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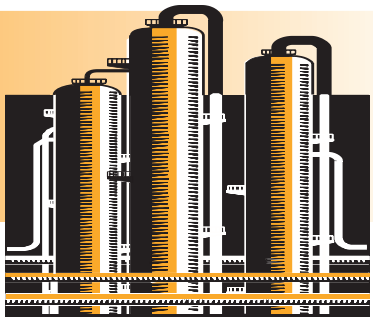
Project Fact Sheet



Gasoline Biodesulfurization

Benefits

- Anticipated 50 percent lower capital costs and 15 to 25 percent lower operating costs than HDS
- BDS does not degrade octane in gasoline
- BDS does not require high temperature, pressure, or collateral processes significantly reducing energy requirements
- Improved environmental standards at lower cost

Applications

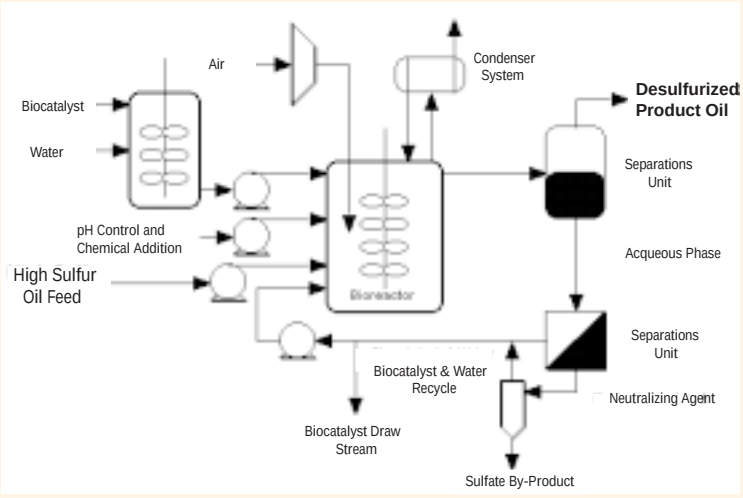
Biodesulfurization may be applied to FCC gasoline to reduce the sulfur content in pool gasoline to less than 200 parts per million (ppm). For those refineries currently hydrotreating the FCC feed, BDS may be used in its stead since HDS carries significant costs for reducing the sulfur levels to less than 200 ppm with the existing technology. BDS is especially well suited to the refineries that process high-sulfur crudes but lack residue upgrading capabilities.

Biodesulfurization will yield lower sulfur gasoline at lower production costs

The biological removal of sulfur from gasoline, a process called biocatalytic desulfurization (BDS), may offer gasoline producers an innovative approach to both energy and cost savings over conventional technologies. Conventional hydrodesulfurization (HDS) of the feed to the fluid catalytic cracking (FCC) unit or of FCC gasoline is an expensive and energy-intensive process requiring high temperature and pressure. Expensive collateral processes are required to generate hydrogen and to convert the main process by-product, hydrogen sulfide, from a toxic, odorous gas into an acceptable product such as elemental sulfur. In addition to sulfur removal, the HDS process saturates olefins in the produced gasoline which results in a deterioration in product quality by lowering octane rating.

BDS offers potential cost savings because the process operates at ambient temperature and pressure and produces a non-toxic by-product eliminating the need for collateral processing of hydrogen sulfide. Biocatalysis is highly selective with the ability to target individual or defined groups of sulfur-containing species, thereby minimizing side reactions such as saturation of olefins. Consequently, BDS retains the quality and value of the gasoline produced.

Gasoline Biodesulfurization Process Flow Diagram



Preliminary process design to develop solvent-tolerant organisms and to test gasoline biodesulfurization at the bench scale.

Project Description

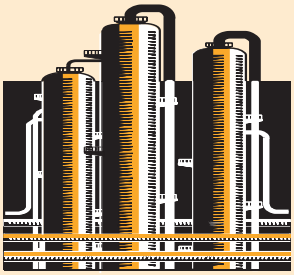
Goal: Develop a biocatalyst and a process to economically reduce the sulfur content of FCC gasoline from 1,000 ppm to 100 ppm.

Bacterial strains that produce enzymes that will utilize the sulfur in thiophenes and benzothiophenes as the sole sulfur source for growth must be isolated and characterized. The genes responsible for the sulfur biotransformation must be isolated, cloned and over-expressed. The biochemical activity of the desulfurization enzymes as well as any other necessary physiological attributes must be optimized to function at maximum efficiency in the BDS process. If necessary, the genes will be engineered into a gasoline tolerant host organism.

A suitable bioreactor system must be developed that affects contact between the bacterial cells and the gasoline. This should be done in a way that is not deleterious to either the biocatalyst or the quality of the gasoline and will not pose a threat to safety. In addition, a suitable product recovery system must be designed.

Progress and Milestones

- The following has been achieved:
  - Applied efficient analytical methods developed to characterize FCC gasoline
  - Isolated desulfurizing bacteria
  - Cloned a gene that appears to code for the desulfurization enzyme
  - Demonstrated *in-vivo* thiophene desulfurization
  - Isolated gasoline tolerant bacteria
  - Developed basic models to describe gasoline BDS
- Development is in progress for the following:
  - Elucidation of the desulfurization pathway including the isolation, identification, and quantification of the pathway intermediates
  - Enhancement of solvent tolerance of the catalyst
  - Definition of the basis for required genetic improvement(s)
  - Determination of the rate and extent of gasoline desulfurization
- The application of gasoline BDS in U.S. refineries is expected to yield savings in domestic gasoline desulfurization of:
  - $900 million in capital equipment
  - $450 million in annual operating expenditures



Project Partners

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